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A multilevel analysis of innovation in developing countries [*]

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Abstract

Innovation is a multilevel phenomenon. Not only characteristics of firms but also the environment within which firms operate matter. Although this has been recognized in the literature for a long time, a quantitative test that explicitly considers the hypothesis that framework conditions affect innovativeness of firms has been lacking. Using a large sample of firms from many developing countries, we estimate a multilevel model of innovation that integrates explanatory factors at different levels of the analysis. Apart from various firm's characteristics, national economic, technological and institutional conditions are demonstrated to directly predict the likelihood of firms to innovate.

Keywords: Innovation, technological capability, multilevel modeling, institutions, developing countries.

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1. Introduction

Already Schumpeter understood the role played by the context for innovation (Schumpeter, 1934). At the most abstract level, the idea about survival of firms propelled by innovation, but determined by the environment, is central to evolutionary economics (Nelson and Winter, 1982). Less abstract but all the more grounded is the argument about sensitivity of innovation to local conditions that is integral to the literature on technological capabilities (Kim, 1980; Dahlman, et al, 1987 and Lall, 1992). Arguing along somewhat similar lines, a need to develop a favourable environment for innovation has been entertained by the technology gap literature (Fagerberg, 1987; Verspagen, 1991) and by the literature on social capabilities (Abramovitz, 1986, 1994). An explicitly multilevel approach is the innovation systems literature according to which firms are embedded in broader innovation systems (Lundvall, 1992, Nelson, 1993 and Edquist, 1997).

Still empirical research on innovation continues to use models confined to single levels of analysis, although relations identified at different levels should be analysed by multilevel modeling (Hox, 2002; Goldstein, 2003 and Luke, 2004). Single-level models assume that observations are independent from each other. If a nested structure of data exits, however, the independence assumption is likely to be violated. By relaxing this assumption, multilevel modeling provides a tool for analysis of firms grouped along various lines. Even more importantly, a proper recognition of data hierarchies allows us to examine new lines of questions in a proper and concise way that could not be done otherwise. Unlike any other method, multilevel modeling directly illuminates the extent to which specific differences between the relevant contexts, such as countries for example, are accountable for outcomes at the firm-level.

The aim of this paper is to demonstrate how research on innovation can benefit from multilevel modeling. Section 2 puts forward arguments for the multilevel approach, particularly in the context of developing countries. Section 3 delineates a basic outline of multilevel models and briefly overviews the methodology. Section 4 introduces the micro dataset derived from the Productivity and Investment Climate Survey (PICS) organized by the World Bank, which rarely has been used in research on innovation; except in recent papers by Almeida, Fernandes (2006) and Goedhuys (2007). Section 5 brings in various measures of the national conditions. Section 6 specifies the bivariate logit multilevel model of innovation and presents results of the econometric estimate. Section 7 overviews the main outcomes and outlines an agenda for future research.

2. A need for multilevel modeling of innovation

Sociologists, geographers or even biologists have recognized for several decades that many kinds of data have a hierarchical structure, and therefore should be analyzed econometrically in a multilevel framework (see, for example, Burstein, 1980; Van den Eeden, Hüttner, 1982; Blalock, 1984; and Draper, 1995). Offspring from the same parents and environment tend to be more alike than those chosen at random from the population. School performance is not only given by the amount of study time of a child, but also by higher-level factors such as characteristics of the class, school or national educational system. Similarly innovation should be seen as a multilevel phenomenon, because not only individual characteristics and capabilities of firms, but also the environment within which firms operate matters for their success in the innovation process.

Already Schumpeter understood the role played by the social context for innovation (Schumpeter, 1934). A key element of his thinking about innovation was the need to overcome resistance to new ways of doing things, which is not only given by the forces of habit imprinted within an individual, but also by how the society is organized. Entrepreneurs need to possess special qualities, or "capabilities" in the contemporary terminology, that allow them to overcome obstacles to innovation in the economy. Schumpeter has perhaps most vividly articulated this insight as follows: "…the reaction of the social environment against one who wishes to do something new… manifests itself first of all in the existence of legal or political impediments…" (Schumpeter, 1934, pp. 86-87). Although Schumpeter emphasized the resistance, the recent literature rather concentrates on factors inside firms and in the society at large that facilitate innovation. Let us briefly consider the most important contributions along these lines.

As has been understood for a long time (Gerschenkron, 1962), emerging from behind represents a great "promise" for technological catch up, but exploitation of this potential requires a favourable environment. At the macro level, the idea that catching up is by no means a free ride has been formalized in the technology gap perspective (Fagerberg 1987 and Verspagen 1991). Arguing about similar lines, but without quantitative measurement or modeling of the relationship, Abramovitz (1986, 1994) entertained the idea that various "social capabilities" matter for development. An important insight from this literature, at least implicitly, is that apart from resources of individual firms, there are factors that operate distinctly at the national level, which can be explicitly modelled in the multilevel econometrics.

Studies of technological upgrading in developing countries have long argued for a need to recognize the importance of national capabilities, but also to understand technological capabilities at the firm level (Kim, 1980; Dahlman, et al, 1987; Lall, 1992; Bell and Pavitt, 1993 and Hobday, 1995). Already Kim (1980) emphasized the role of the external environment represented by customers, suppliers, competitors, government and, last but not least, local research institutions and technical information centres for the ability of local firms to import, adapt and improve foreign technologies. Kim in fact encouraged multilevel analysis of technological catching up: "many variables both at the industry and national levels may, however, account for variations in the development patterns of industrial technology…" (Kim, 1980, pg. 273).

Another important point of this literature is the broad nature of technological capabilities, which span much beyond the traditional focus on research and development (R&D). Innovation in developing countries, which often refers to incremental, gradual and context-specific improvements along the prevailing technological trajectories originating from the advanced countries, is much about diffusion of technology. Bell and Pavitt (1993) argue that most firms in developing countries innovate on the basis of a broad range of practical capabilities which are typically concentrated in the departments of maintenance, engineering or quality control. However, Kim (1980) emphasizes the role of R&D efforts for firms to assimilate foreign technology, so that one should certainly not neglect the latter, especially from a certain stage of development.

Nevertheless, this approach has been never translated into formal modelling. Figueiredo (2006), in a recent survey, points out that more empirical testing of the link between firms and other external factors is needed before conclusive results can be reached. Although this literature has offered important practical insights about how firms innovate in developing countries and no doubt has been important for inspiring research along these lines, an approach that would allow us to replicate these findings through quantitative research on large firm-level datasets has been lacking.

As has been already anticipated above, most of the recent debate is organized around the concept of innovation systems (Lundvall, 1992; Nelson, 1993 and Edquist, 1997). A central argument underlying this literature, which is explicitly multilevel, is that innovation is determined by factors operating at different levels. Spatial concentration of relevant actors, resources and other environmental factors conducive to learning influences firms' innovative performance. A firm embedded in a vibrant environment may therefore become a successful innovator, while the very same firm in a considerably less favourable environment may fail to innovate. Such systems can be analyzed at different hierarchical levels, and various variables can be defined at each level. It cannot be emphasized enough, however, that the firm should always remain the ultimate unit of the analysis.

Most of the existing literature has used exclusively macro data to gauge differences in innovation performance across countries (Furman, at al., 2002; Archibugi, Coco, 2004; Fagerberg, Srholec, 2006; Fagerberg, et al., 2007). Some studies using micro data have been performed recently for more than one country (Janz, et al., 2004; Mohnen and Röller, 2005; Mohnen, et al., 2006; Griffith, et al., 2006; Almeida and Fernandes, 2006), but the contextual factors have been at best represented by a set of country dummies without a serious attempt to actually explain the cross-country differences. Not much can be therefore concluded from the existing literature on how the technological, economic and social environment influences the innovation process in firms. A complex phenomenon, such as the innovation process, cannot be fully understood at any single level of analysis.

An important bottleneck for future deepening of research in this tradition is that the empirical analysis is far behind our theoretical understanding of the multilevel nature of innovation. Abundance of theoretical reasoning about role of the context is in sharp contrast with the general lack of quantitative work aimed at validating these hypotheses. At this front multilevel modeling has much to offer. Using the multilevel perspective, we can reach beyond the dichotomy between methodological individualism and collectivism in empirical research on innovation. Such a perspective is particularly required for research on technological catching-up, because there is considerable variety in the contextual factors among developing countries. To show how this can be done is the main purpose of the following.

3. A logit model of firms nested in countries

A multilevel model, also known as hierarchical, random coefficient, variance component or mixed-effects model, is a statistical model that relates a dependent variable to explanatory variables at more than one level (Luke, 2004). Assume 2-level structure with firms at level-1 nested in countries at level-2. A standard 1-level model is the following:

(1) $$y_{ij} = \beta_{0j} + \beta_{1j} x_{ij} + e_{ij}$$

where y_{ij} is the dependent variable, x_{ij} is the firm level explanatory variable, β_{0j} is the standard intercept, β_{1j} is the standard slope coefficient, e_{ij} is the standard residual error term, i is the firm ($i = 1 \ldots n$) and j is the country ($j = 1 \ldots m$). Although we allow for more than one country in the analysis, the equation is formulated separately for each of them. If we are interested only in this relationship, we can estimate the m models separately, assuming different parameters for each country and a common intra-country residual variance. A linear 2-level model with explanatory variables at both firm and country levels emerges, if we let the intercept β_{0j} and slope β_{1j} to become random variables:

(2) Level-1 linear model:

$$y_{ij} = \beta_{0j} + \beta_{1j}x_{ij} + e_{ij}$$

Level-2 model:

$$\beta_{0j} = \gamma_{00} + \gamma_{01}z_j + u_{0j}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}z_j + u_{1j}$$

where z_j is the level-2 predictor and u_{0j} and u_{1j} are normally distributed residual terms for each level-2 equation, which are independent from the level-1 residual e_{ij}. Since the level-2 effects are identified by the subscript j, we have a hierarchical system of regression equations, where we are allowing each country to have a different average outcome (β_{0j}) and a different effect of the level-1 predictor on the outcome (β_{1j}). Although a different level-1 model is estimated for each country, the level-2 equation is defined for all of them. By substituting β_{0j} and β_{1j} into the level-1 model and rearranging we can write the entire model in a single equation:

(3) $$y_{ij} = \gamma_{00} + \gamma_{01}z_j + \gamma_{10}x_{ij} + \gamma_{11}z_jx_{ij} + (u_{0j} + u_{1j}x_{ij} + e_{ij})$$

where in brackets is the random part and the rest contains the fixed part of the model. As discussed by Goldstein (2003), the presence of more than one residual term makes the traditional estimation procedures such as ordinary least squares inapplicable and therefore specialized maximum likelihood procedures must be used to estimate these models. For more details on these estimators see Raudenbush, et al. (2004).

So why should we use multilevel modeling? A major assumption of single-level models is that the observations are independent from each other. If a nested structure of data exits, units belonging to the same group tend to have correlated residuals and the independence assumption is likely to be violated. By relaxing this assumption, multilevel modeling provides statistically more efficient estimates, which are more "conservative", as Goldstein (2003) puts it, than those ignoring the hierarchical nature of data. Statistically significant relationships that have been established in the literature by using the standard methods may come out not significant in the multilevel analysis. A lot that we have learned empirically about innovation in firms from research on data at the aggregate level might appear different in the multilevel framework.

Apart from the statistical consequences, a proper recognition of data hierarchies allows us to examine new lines of questions. Using the example of firms in countries, the multilevel approach enables the researcher to explore the extent to which specific differences between countries are accountable for outcomes at the firm level. It is also possible to investigate the mechanics by which the national factors operate at the firm level and the extent to which these effects differ for different kinds of firms. For example, we may analyse whether differences in national framework conditions are more important for smaller than larger firms. Such research questions can be straightforwardly examined by multilevel modeling, but can be neither easily nor properly examined by the standard methods.

A common approach to control for the compositional effects is to ignore the random variability associated with the higher-level factors and include into the estimate fixed effect dummies that correspond to the hierarchical structure of the data, such as relevant dummies for sectors, regions or countries. Using dummies might be a useful quick-fix solution, if the purpose only is to control for the compositional effects, but it is of a little help if the prime interest is in effects of the higher-level factors or cross-level interactions themselves. Although we may detect rough patterns of the structure, a dummy is a "catch-all" variable for which we can only speculate what it really represents. After all, if these dummies significantly improve the predictive power of the model, which is typically the case in econometric estimates, a multilevel analysis should be chosen.

Analyses that exclusively use micro data to study the effects of environment on firms suffer from issues of endogeneity. A good example is the set of variables on obstacles to innovation in Community Innovation Surveys (OECD, 2005). Even though most of these obstacles, such as lack of customer interest or excessive regulation, refer to factors that are supposed to be external to the firm, these variables fail to properly measure the environmental effects. Innovative firms systematically report more severe obstacles to innovation, because they are arguably more aware of what is hindering innovation than firms that do not innovate. An inevitable outcome of a single-level analysis is therefore a highly positive correlation between innovativeness and these external obstacles to innovation (Evangelista et al., 2002; Mohnen and Röller, 2005), but this is mainly because innovation influences firm's perception of the obstacles (Clausen, 2008), not the other way. A multilevel model should be used for this purpose, where we include objective characteristics of the environment, not only firms' perceptions about it.

Another important reason for using multilevel modeling to study innovation is more theoretical in nature. A central argument in the literature is that firms are embedded in the environment, and therefore the theory implicitly predicts a nested structure of micro data. In other words, the basic assumption of the standard multiple regression models on independent residuals is expected to be violated from the outset. Empirical research that uses single-level models to study how framework conditions influence innovation therefore suffers from a methodological contradiction. If a researcher aims to test hypotheses that are operating at different levels, a multilevel statistical model is the most appropriate one.

So far we have assumed that the dependent variable is continuously distributed. If the dependent variable is binary, we need to specify a non-linear multilevel model. For this purpose, we assume a binomial sampling model and use a logit link function to transform the level-1 predicted values. Only the level-1 part of the model differs from the linear case and the multilevel model can be delineated as follows:

(4) Level-1 logit model:

$$E\,(y_{ij} = 1 \mid \beta_j) = \varphi_{ij}$$

$$\mathrm{Log}\,[\varphi_{ij} / (1 - \varphi_{ij})] = \eta_{ij}$$

$$\eta_{ij} = \beta_{0j} + \beta_{1j}x_{ij}$$

Level-2 model:

$$\beta_{0j} = \gamma_{00} + \gamma_{01}z_j + u_{0j}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}z_j + u_{1j}$$

where η_{ij} is the log of the odds of success, such as for example the propensity of a firm to introduce innovation. Although φ_{ij} is constrained to be in the interval (0,1), the logit transformation allows η_{ij} to take any value and therefore can be substituted to the structural model. From this follows that the predicted log-odds can be reversed to odds by $exp(\eta_{ij})$ and to the predicted probability φ_{ij} by $exp\{\eta_{ij}\}/(1+exp\{\eta_{ij}\})$.[1]

[1] Note that there is no term for the level-1 residual in the model because for binary dependent variables the variance is completely determined by the mean and thus a separate error term is not estimated; for more detailed explanation see Luke (2004, pg. 55).

4. Micro data

At the firm-level we use a large micro dataset derived from the Productivity and Investment Climate Survey (PICS) organized by the World Bank. Firms were asked about various aspects of their business activities, including a set of questions on innovation and learning, in a questionnaire harmonized across many developing countries. For more details on methodology of the survey see World Bank (2003).

The main focus of this paper is on direct evidence on innovation in firms. INNPDT is a dummy with value 1 for firms that answered positively on a question whether they "developed a major new product line", which broadly corresponds to the concept of product innovation.[2] It is important to bear in mind that these innovations are new to the firm, but not necessarily new to the market or to the world, which is pivotal for interpretation of this information in the context of developing countries.

Besides evidence on innovation, the dataset provides information on size, age, industry and various facets of firm's technological capabilities. SIZE is the natural logarithm of the number of permanent employees in the initial year of the reference period; for more about the period see below. Apart from scale economies, size is important to control for due to definition of INNPDT, which is going to be the dependent variable in the econometric estimate. Since this is a dummy for introducing

[2] It is interesting to notice that apart from being rather short, there is no explicit reference to "technologically" new product in the PICS definition. One may argue, however, if a more complicated question would be feasible to ask in developing countries, where awareness about "technological" aspects of innovation is often limited. Simpler may be actually better in this context, at least as far as the response rate and the comparability of the answers are concerned. Furthermore, while the 2nd revision of the Oslo Manual (OECD, 1997) emphasises "technological" nature of innovation, the 3rd revision of the Oslo Manual (OECD, 2005) does not explicitly refer to "technologically new developments" anymore, which makes the idea about innovation in CIS somewhat closer to the more general definition in PICS.

at least one innovation, larger firms should be more likely to report a positive answer because they often comprise multiple products under a single roof.

AGE is the natural logarithm of the number of years since the firm has begun operations in the country. On one hand older firms tend to have more accumulated knowledge and other resources to capitalize on, but on the other hand newly established firms, and therefore younger firms, may appear more innovative because by definition they need to introduce a new product when they launch their business. It will be interesting to see, which of these effects dominate the results.

Sectors were difficult to identify because somewhat different classifications had been used in the various national datasets. For this reason we can distinguish only between 13 broad sectors as follows: 1) Agro, food and beverages; 2) Apparel, garments, leather and textiles; 3) Chemicals; 4) Wood, paper, non-metal materials and furniture; 5) Metal; 6) Machinery, electronics and automobiles; 7) Construction; 8) Hotels and restaurants; 9) Trade; 10) Transport; 11) Real estate and other business services; 12) Other industry (mining, energy, water, recycling); and 13) Other business services. SECTOR dummies are used in the econometric estimate to control for the sectoral patterns with “Agro, food and beverages” as the base category.

Structural patterns like these are necessary to control for, but even more essential predictors of success in the innovation process are capabilities and resources of firms directly devoted to search, absorption and generation of new technology. An important insight of the aforementioned literature on innovation in developing countries is the broad and multifaceted nature of technological capabilities. It is very fortunate for our purpose that the survey contains a battery of variables that may be used to gauge their various facets.

Research and development (R&D) is the traditional, and for a long time the only, seriously considered indicator of technological capabilities. R&D is defined as a dummy with value 1 if the firm devotes expenditure on this activity. The aim of this variable is to capture a general commitment to R&D.[3] Nevertheless, it cannot be emphasized enough that innovation is about much more than just spending on R&D, especially in the context of developing countries, so that we need to keep an eye on these broader aspects of technological capabilities as well.

Besides the R&D variable, the dataset provides information on structure of employment by occupation, adherence to ISO norms, use of internet in the business and formal training of employees. PROF is a variable that refers to the share of professionals in permanent employment, which includes specialists such as scientists, engineers, chemists, software programmers, accountants and lawyers, and reflects the extent of highly qualified human capital.[4] ISO is a dummy with value 1 if the firm has received ISO (e.g. 9000, 9002 or 14,000) certification and thus reflects a capability to conform to international standards of production. WWW is a dummy with value 1 if the firm regularly uses a website in its interaction with clients and suppliers, which

[3] Although most of the national questionnaires include information on the actual value of R&D expenditure and sales, we refrain from using this to compute an intensity measure, because there is missing data for at least one of them in several thousands of firms, and because of concerns about comparability (and measurement error) of the reported amount of R&D expenditure (which is often based on rough estimates). To our judgement the dummy variable on whether a firm spends on R&D or not is much more robust in this respect.

[4] Since some versions of the PICS questionnaire did not distinguish between professionals and managers, the PROF variable also covers the latter category (but excluding those involved in shop floor supervision). As often happens to variables of this kind, 23 firms mistakenly reported employing more professionals than the total number of employees, for which the PROF variables was changed into missing.

captures the potential for user-producer interactions mediated by the internet. And finally SKILL is a dummy with value 1 if the firm provides formal (beyond “on the job”) training to its permanent employees.

It is interesting to note that many of these facets of technological capabilities, such as training, human resources, quality control and use of information technologies, have been emphasized as particularly relevant but under-measured in the context of developing countries in the third edition of the Oslo Manual (OECD, 2005, pp. 141-144). Along these lines the PICS data provides much richer evidence as compared to what can be derived from most of the CIS surveys that have been conducted in developing countries so far.

Another major advantage of PICS is that all of the information, including the R&D, PROF, ISO, WWW and SKILL variables, is available for both firms that innovated as well as for those that did not, whereas only the innovators answer most (and the most interesting part) of the CIS questionnaire. This design of the CIS survey severely limits any inferences that can be made about factors behind success in the innovation process, because we actually do not know much about those that do not innovate. An important side effect of this is that any study that uses the more detailed information from CIS data should control for a potential sample selection bias, which is difficult to identify precisely due to the lack of information. But robustness with regards to identification of the selection equation is seldom discussed in these studies, although arguably the results are often sensitive to specification of the exclusion restriction.

A basic overview of the dataset is given in Table 1. About 21,000 firms with at least some information on these variables are in the dataset. Almost 40% of the firms answered positively on the question about INNPDT. It might seem surprising that so many firms innovated in a sample of mainly developing countries; however one needs to keep in mind that these are “new to the firm” innovations, which often reflect diffusion of existing technology, as discussed in more detail below. About a quarter of the sample consists of firms with less than 10, two-thirds of the firms had less than 50, whereas roughly a tenth of the sample had more than 250 permanent employees. A quick look at composition of the sample by age reveals that around 15% of the firms did not operate for more than 5 years, and a fifth of them were older than 25 years. Averages of the variables reflecting technological capabilities are self-explanatory, and will be examined in more detail later in relation to the propensity to innovate in the econometric framework.

Table 1: Overview of micro data

Variable	Obs.	Mean	Std. Dev.	Min	Max
INNPDT	20,842	0.376	0.484	0	1.00
SIZE	19,728	3.331	1.677	0	9.93
AGE	20,883	2.554	0.807	0	6.43
R&D	17,986	0.238	0.426	0	1.00
PROF	20,372	0.131	0.183	0	1.00
ISO	20,694	0.187	0.390	0	1.00
WWW	20,900	0.507	0.500	0	1.00
SKILL	20,150	0.414	0.493	0	1.00

Source: Own computations based on World Bank (2003).

5. Macro data

Since we are going to use a multilevel model, we obviously need data for specific country-level variables that can capture salient aspects of the national framework conditions. To limit influence of shocks and measurement errors occurring in specific years, we use the macro indicators in the form of three-year averages over period prior to the year when the survey was conducted, if not specified otherwise below.[5] Also using three-year averages limits the extent of missing data, which is crucial in a sample containing many developing countries. Still missing information at the country level had to be estimated in some cases, which is explained for particular indicators below.

A natural starting point is to look at patterns of the micro dataset by country, which is revealed in Table 2. Surveys conducted in 28 countries are included, most of which are developing. Although the survey has been harmonized under the aegis of the World Bank, there are differences between the national datasets that need to be addressed. For example a closer look at the national questionnaires reveals some subtle modifications in particular phrasing of the questions in different waves of the survey. To account for these differences, we GROUP countries along these lines, see the third column of the table, and include dummies for these groups into the regression estimate. [6]

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[5] Since the surveys were conducted in different years, we kept this in mind when constructing the country-level variables, so that we computed averages over different three-year periods depending of the timing of the survey in the particular country.

[6] It should be stressed, however, that only countries with rather minor differences in the questionnaire were allowed to enter the analysis. For example, INNPDT refers to a question whether the firm has "Developed a major new product" in GROUP 1, "Developed successfully a major new product line/service" in GROUP 2 and "Developed a major new product line" in GROUP 3. Even more importantly this variable refers to the period over the last three years in GROUPs 1 and 2, but over the

Table 2: Overview of the dataset by country

Country	Year	GROUP	Obs.	INNPDT	GDPCAP
Cambodia	2003	1	503	0.54	1,819
Chile	2004	3	948	0.47	9,479
Ecuador	2003	1	453	0.52	3,343
Egypt	2004	3	977	0.15	3,625
El Salvador	2003	1	465	0.62	4,597
Germany	2005	2	1,196	0.18	26,134
Greece	2005	2	546	0.25	19,313
Guatemala	2003	1	455	0.53	4,044
Honduras	2003	1	450	0.47	2,878
Hungary	2005	2	610	0.28	14,836
India	2005	3	2,286	0.40	2,673
Indonesia	2003	3	713	0.38	2,980
Ireland	2005	2	501	0.39	32,666
Kazakhstan	2005	2	585	0.28	5,921
Korea	2005	2	598	0.38	18,271
Morocco	2004	1	850	0.25	3,815
Nicaragua	2003	1	452	0.47	3,158
Poland	2005	2	975	0.35	11,608
Portugal	2005	2	505	0.14	18,849
Romania	2005	2	600	0.32	7,193
Russia	2005	2	601	0.35	8,387
Saudi Arabia	2005	3	681	0.57	13,707
South Africa	2003	1	603	0.68	8,890
Spain	2005	2	606	0.29	23,107
Thailand	2004	3	1,385	0.50	6,722
Turkey	2005	3	1,323	0.36	6,610
Ukraine	2005	2	594	0.49	5,281
Vietnam	2005	2	500	0.21	2,412

Note: Number of observations used in the estimates differs across specifications of the model due to missing data for particular variables.
Source: Own computations based on World Bank (2003).

last two years in GROUP 3. A large group of countries mostly from Latin America, where the survey has been conducted in 2006, cannot be included because this version of the questionnaire used a much broader phrasing of this question. Also data from earlier surveys conducted in Brazil, Philippines and China had to be excluded, and with a heavy heart, because the questionnaire was strictly speaking not comparable for various reasons. It may also be noted that another question in the survey provides information on whether firms “substantially changed the way the main product is produced”, which broadly refers to process innovation. However, this question differs between countries to an extent that makes the data incomparable, and therefore we refrain from using this information.

Another issue is whether the data are representative. Since we fully acknowledge this concern, we have included into the sample only national datasets with about five hundred and more observations. Even this could be seen as a relatively low number by some observers; in particular by those who have the fortune to analyse large CIS dataset. However, we should not judge these data by the European standards, because most of the sample comes from developing countries for which micro data on innovation are extremely scarce. In fact, one can find plethora of papers in the literature based on samples of a few hundreds of firms, which at least implicitly claim to be representative to the context in question. Moreover, better micro data on innovation for a reasonably large number of developing countries is not likely to emerge anytime in the near future.[7]

Let us focus on the patterns of INNPDT by country. Less than 20% of firms innovated in Portugal, Egypt and Germany, but more than 55% of firms claimed to introduce a major new product in Saudi Arabia, El Salvador and South Africa. What accounts for such similarities and differences across different countries? Why do firms innovate less in Egypt than in Saudi Arabia? And why appear firms in the advanced EU member countries, with the notable exception of Ireland, among the least innovative according to these data? Such questions are at the core of the interest in this paper.

An important reason for the relatively high frequency of innovation in many developing countries, as already anticipated above, is that the INNPDT variable refers to products "new to the firm", but not necessarily new to others. Since firms in developing countries can benefit from diffusion of technologies developed in frontier

[7] Some developing countries have conducted surveys based on the CIS methodology (UNU-INTECH 2004), but access to micro data from these surveys remains limited, which prevents pooling them together for the purpose of multilevel analysis.

countries, all else equal, they should be more likely to introduce "new to the firm" innovation. A large part of what is captured by the INNPDT variable arguably reflects "innovation through imitation", which in the context of developing countries does not at all make this information less relevant economically, quite the opposite.

Before diving more deeply into explaining these patterns in the econometric framework, let us therefore briefly examine differences between countries at different levels of development. As an overall measure, Table 2 provides information on GDP per capita in PPP (constant 2000 international USD), which refers to the GDPCAP variable in the following. From a cursory look at the data there seems to be a connection. Statistically speaking the "unconditional" correlation between the propensity of firms to innovate and development of the country is -0.33, so that the potential for diffusion is relevant, but obviously not the only or perhaps not even the main explanation. Many other national factors seem to be at play, which is encouraging for the following search for them.

A natural starting point is to consider the quality of the national science, research and educational systems (Nelson, 1993). Availability of research infrastructure, like universities, R&D labs and a pool of researchers in the labour force, reduce costs and uncertainties associated with firm's innovative activities. Although some part of these resources is devoted to basic research, most research in developing countries is arguably geared toward fostering the capacity to assimilate knowledge from abroad rather to generate new knowledge at the frontier. For example, Kim (1997) was well aware of this fact, and used the notions of technological capability and absorptive capacity interchangeably in the Korean context.

As measures of the national research infrastructure, we use a set of indicators that has been readily employed for this purpose in the literature (Furman, et al., 2002; Archibugi and Coco, 2004; Fagerberg, et al. 2007). ARTICLE refers to the number of scientific articles published in journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI) per capita, which has been derived from the World Bank (2007). PATENT represents the number of international PCT (Patent Co-operation Treaty) patent applications per capita recorded in the WIPO database. GERD refers to expenditure on R&D as % of GDP, which have been gathered from various sources, including UNESCO, RICYT and World Bank (2007). For these indicators only the GERD data in Saudi Arabia had to be estimated. [8]

In addition, we consider two aspects of the technological infrastructure, equivalent to some of those that are used to capture the wider facets of technological capabilities at the firm level, which diffusion in the economy is expected to generate positive effects for the local firms. ISO for which data has been derived directly from the International Organization for Standardization refers to the number of ISO 9000 certifications per capita, and is supposed to reflect quality of the local supply base (and also of the local business customers for that matter). INTERNET is the number of internet users per capita, which refers to people with access to the worldwide network, based on data from World Bank (2007). No missing data had to be estimated here.

Education is at the heart of what Abramovitz (1986) would refer to as social

[8] Since information on R&D employment is available for Saudi Arabia, we have used this information to estimate the GERD figure, assuming that this is proportional to the relative position of the country in terms of R&D employment per capita. Although it might have been generally preferable to use information on R&D employment in the following, we use data on expenditure, because the former is missing for three other countries in the sample, so that more data would have to be imputed.

capabilities, represented by LITER, EDUSEC and EDUTER variables. LITER refers to the literacy rate in adult population (% of people ages 15 and above), while EDUSEC and EDUTER are gross enrolment rates in secondary and tertiary education respectively; all derived from UNESCO. Since there is a relatively low frequency of data on literacy, we use the latest year available for this indicator, and complement the information in few cases by estimates from various issues of the Human Development Report. The EDUTER variable for Ecuador had to be estimated by average imputation. It would have been preferable to have data on net (rather than gross) enrolments, or even better on educational attainment of the population, but this information is not available for many countries in the sample. Similarly, data on science and engineering education, which would have been interesting to take into account, are unfortunately not widely available.

A salient aspect of the national framework conditions that certainly concerns every profit-seeking entrepreneur is the income tax rate, which has direct implications for net (after-tax) rewards from innovation. Since the detrimental effect increases with more progressive taxation, TAXINC refers to the highest marginal tax rate, derived from World Bank (2007). It would be more relevant to use the "effective" tax rate, because tax deductions may offset the nominal tax rate, but this information is not available for this sample of countries.

Another relevant feature of the institutional framework is regulation of business, for which data from the "Doing Business" project in the World Bank, which follows Djankov, et al. (2002), Djankov, et al. (2003) and Botero, et al. (2004), comes very handy. Unfortunately, data for most of these indicators exist only for the recent years.

Still we have been able to derive three variables, for which the data stretch back to 2003. ENTRY refers to the number of days required for an entrepreneur to start up a business. EMPREG is the rigidity of employment index, which overviews rules for hiring, firing and employing workers. ENFORCE measures the number of days required to resolve a commercial dispute. For more details on definitions see World Bank (2005).

Furthermore, we take into account general "rules of the game" formalized in the national constitution. An overall measure that provides comparison among many countries is the POLITY2 index developed by Marshall and Jaggers (2003), which measures the degree of democracy versus autocracy on a Likert scale with 20 degrees (from -10 for autocratic to +10 for democratic constitution). To make a long story short, countries with "western" institutional framework rank high on the POLITY variable, while countries with constitutions that do not conform to the democratic ideals of the west get a low mark.

Although macroeconomic instability is not a serious matter of concern in most advanced countries, at least in the recent period, turbulences along these lines are an essential part of the picture in developing countries. Since innovation is already quite uncertain venture by itself, anything in the environment that may further increase uncertainty, such as the symptoms of macroeconomic volatility mentioned below, should hinder the appetite of firms for innovation. INFLAT reflects price stability, which is measured by geometric average of inflation based on GDP deflator. EXRATE refers to coefficient of variation of the official exchange rate (LCU/USD). CURRACC is current account balance in % of GDP. FISCAL refers to balance of the government budget in % of GDP. UNEMP is the unemployment rate (% of total labor force). All of these indicators come from World Bank (2007), except of FISCAL that has been derived from the IMF (International Financial Statistics).

Finally, import of technology from abroad is often cited as an indispensable element of successful technological catch up. Many different channels of international technology transfer have been considered in the literature over the years, including trade, foreign direct investment, licensing, migration or collaboration on innovation. Due to a lack of data on the latter channels, we take into account only IMPORT, which refers to import of goods and services, and FDI, which is inflow of foreign direct investment; both in % of GDP. Since large economies for natural reasons trade/invest relatively more internally, we control for size of the country given by the log of population LNPOP, if these variables are introduced in the estimate. IMPORT and LNPOP have been derived from World Bank (2007), whereas FDI comes from UNCTAD (Foreign Direct Investment database).

Although there is a straightforward theoretical distinction between the potential for diffusion and the "conditional" factors that determine whether this "great promise" is realized, another matter is to be able to distinguish between them empirically. All too many relevant indicators tend to be extremely correlated to GDPCAP and to each other, which makes it problematic to use them simultaneously in a regression due to concerns about multicollinearity. A cursory look at correlations between the indicators considered above reveals that this is indeed a serious problem, especially for those that reflect the quality on the national innovation system. Since it is empirically impossible to disentangle between the effects of GDPCAP, ARTICLE, PATENT, GERD, ISO, WWW, LITER, EDUSEC and EDUTER, we follow Fagerberg, et al. (2007) and use factor analysis to construct an overall measure that can represent their joint impact.

Table 3 shows the results. All of the indicators are used in logs, partly because of non-linearity in the potential for diffusion as commonly assumed in the literature, but also because outliers in some variables were detected, especially for those on per capita basis. Only one factor score, labelled TECH, with eigenvalue higher than one was detected, explaining 74.4% of the total variance. So-called factor loadings, which are the correlation coefficients between the indicators (rows) and the principal factor (column), are reported in the upper part of the table. Since all the indicators come out with high loadings, and many of them are actually even more direct measures of technology than the GDPCAP variable itself, we shall use the factor score on TECH generated by this estimate as an overall measure of technological level of the country in the following.

Table 3: Results of the factor analysis

	TECH
GDPCAP	0.93
ARTICLE	0.94
PATENT	0.80
GERD	0.77
ISO	0.94
INTERNET	0.94
LITER	0.67
EDUSEC	0.87
EDUTER	0.87
Eigenvalue 1	6.69
Eigenvalue 2	0.58
Eigenvalue 3	0.29
Eigenvalue 4	0.11
Eigenvalue 5	0.04
Eigenvalue 6	-0.03
Eigenvalue 7	-0.04
Eigenvalue 8	-0.06
Eigenvalue 9	-0.08
% of total variance explained by the retained factor	74.4
Number of observations	28

6. Econometric analysis

The aim is to explain likelihood of firms to innovate by factors operating at the firm (i) and country (j) levels. $INNPDT_{ij}$ is the dependent variable. $SIZE_{ij}$, AGE_{ij} and a vector of the firm's capabilities $CAP_{ij} \in$ ($R\&D_{ij}$, $PROF_{ij}$, ISO_{ij}, WWW_{ij} and $TRAIN_{ij}$) are the level-1 predictors, while the potential for diffusion given by the position of the country where the firm is nested at the technological ladder $TECH_j$ and a vector of the conditional factors for exploiting this potential $CON_j \in$ ($TAXINC_j$, $ENTRY_j$, $EMPREG_j$, $ENFORCE_j$, $POLITY_j$, $INFLAT_j$, $EXRATE_j$, $CURACC_j$, $FISCAL_j$, $UNEMP_j$, $LNPOP_j$, $IMPORT_j$ and FDI_j) are the level-2 predictors. In addition, we control for sectoral patterns and differences in the questionnaire, as explained above, by including a set of relevant dummies $DUMMY_{ij} \in (SECTOR_{ij}, GROUP_{ij})$.

Let's assume, for the sake of the exposition, that CAP_{ij}, CON_j and $DUMMY_{ij}$ refer only to a single variable. Full specification of the model with a complete set of fixed and random effects is then as follows:

(5) Level-1 logit model:

$$E\ (INNPDT_{ij} = 1 \mid \beta_j) = \varphi_{ij}$$

$$\text{Log}\ [\varphi_{ij} / (1 - \varphi_{ij})] = \beta_{0j} + \beta_{1j}SIZE_{ij} + \beta_{2j}AGE_{ij} + \beta_{3j}CAP_{ij} + \beta_{4j}DUMMY_{ij}$$

Level-2 model:

$$\beta_{0j} = \gamma_{00} + \gamma_{01}TECH_j + \gamma_{02}CON_j + u_{0j}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}TECH_j + \gamma_{12}CON_j + u_{1j}$$

$$\beta_{2j} = \gamma_{20} + \gamma_{21}TECH_j + \gamma_{22}CON_j + u_{2j}$$

$$\beta_{3j} = \gamma_{30} + \gamma_{31}TECH_j + \gamma_{32}CON_j + u_{3j}$$

$$\beta_{4j} = \gamma_{40} + \gamma_{41}TECH_j + \gamma_{42}CON_j + u_{4j}$$

where there are level-1 fixed effects ($\gamma_{00} \ldots \gamma_{40}$), level-2 fixed effects for the intercept (γ_{01} and γ_{02}), cross-level fixed effects ($\gamma_{11} \ldots \gamma_{42}$) and random effects ($u_{0j} \ldots u_{4j}$); of which γ_{00} is the estimated grand average of the log-odds of firms to innovate across countries, $\gamma_{10} \ldots \gamma_{40}$ are the estimated averages of the firm-level slopes across countries, γ_{01} is the estimated effect of the position of the country at the technological ladder, γ_{02} refers to the effect of the other national predictors, $\gamma_{11} \ldots \gamma_{42}$ capture the cross-level interactions between the firm- and country-level predictors, u_{0j} tells us that the intercept vary around the grand average between countries, and $u_{1j}...u_{4j}$ indicate that the slopes vary not only as a function of the predictors, but also as a function of a unique country effects.

A large number of cross-level fixed effects can emerge in the full specification, depending on the number of variables included in the CAP_{ij} and CON_{j} vectors, many of which are often not viable to estimate for concerns about reduced parsimony, degrees of freedom, problems of multicollinearity and their difficult interpretation. Nevertheless, this is just a general outline of the model, and there is a variety of reduced specifications that can be estimated for the particular research question in mind. For example, the so-called "intercept-as-outcome" model with only the intercept as a function of level-2 predictors, without considering any of the potentially numerous cross-level fixed effects, is possible to estimate. Since there is relatively limited number of countries in the sample, which constrains the number of parameters to be estimated, this is the strategy that we are going to follow. Also we do not allow the set of $SECTOR_{ij}$ and $GROUP_{ij}$ dummies to vary across countries, which helps us to greatly reduce the number of random effects without losing much content.

By focusing on the "intercept-as-outcome" model, we test the hypothesis that the various national characteristics directly influence the likelihood of firms to innovate. To improve interpretability of the results, we standardized the country-level predictors by deducting mean and dividing by standard deviation, so that these variables enter the estimate with mean of zero and standard deviation equal to one. Standardization of the variables implies that all of these predictors have meaningful zero-points, which simplifies meaning of the estimated parameters. Since standardization transforms the variables to a common scale of units of standard deviation, another advantage of this procedure is that the magnitude of the estimated coefficients – so-called "beta" coefficients - can be directly compared.

Table 4 gives the results. [9] Fixed effects are reported in the upper part, separately for the intercept and slopes, while random effects are in the lower part of the table.[10] Since it is often illuminating to start with a basic specification and then extend the model by adding more predictors, we include the country-level variables in three steps. Along with $TECH_j$, which is indispensable in the model as a measure of the potential for diffusion, in the first column we include the variables that reflect institutions, in the second column we add the set of variables that captures the macroeconomic conditions, and finally in the third column we extend the model by the variables on openness to imports and foreign direct investment. After considering the full set of predictors, we reduce the country-level variables to only those that came out statistically significant at conventional levels, which provides the "best" model in the fourth column.

[9] A specialized statistical software Hierarchical Linear and Non-linear Modeling (HLM) version 6.04 was used to estimate the equations. Since there is a relatively low number of countries in the sample, we use the restricted maximum likelihood procedure, which should be more robust to reduced degrees of freedom than the full maximum likelihood estimate. See Raudenbush, et al. (2004) for details on the estimation procedure.

[10] For the sake of space, we do not report the estimated fixed effects of the $SECTOR_{ij}$ and $GROUP_{ij}$ dummies, which do not merit much interest here, but we indicate in the table whether these are included or not.

Table 4: Econometric results

	(1)	(2)	(3)	(4)
Fixed Effects:				
For intercept$_{ij}$ (β_{0j})				
Intercept$_{ij}$ (γ_{00})	-0.97 (0.19)***	-1.02 (0.16)***	-1.01 (0.18)***	-1.12 (0.15)***
TECH$_{j}$ (γ_{01})	-0.42 (0.14)***	-0.41 (0.14)***	-0.40 (0.18)**	-0.26 (0.11)**
TAXINC$_{j}$ (γ_{02})	-0.38 (0.09)***	-0.28 (0.07)***	-0.38 (0.08)***	-0.36 (0.06)***
ENTRY$_{j}$ (γ_{03})	-0.15 (0.08)*	-0.15 (0.06)**	-0.15 (0.07)**	-0.13 (0.06)**
EMPREG$_{j}$ (γ_{04})	-0.03 (0.08)	-0.09 (0.07)	-0.00 (0.08)	..
ENFORCE$_{j}$ (γ_{05})	-0.08 (0.07)	-0.13 (0.06)*	-0.01 (0.09)	..
POLITY$_{j}$ (γ_{06})	0.48 (0.09)***	0.64 (0.08)***	0.59 (0.09)***	0.59 (0.07)***
INFLAT$_{j}$ (γ_{07})	..	-0.20 (0.06)***	-0.18 (0.06)**	-0.16 (0.05)***
EXRATE$_{j}$ (γ_{08})	..	-0.21 (0.08)**	-0.20 (0.08)**	-0.23 (0.07)***
CURACC$_{j}$ (γ_{09})	..	0.18 (0.07)**	0.17 (0.08)*	0.18 (0.06)***
FISCAL$_{j}$ (γ_{010})	..	-0.05 (0.06)	0.09 (0.08)	..
UNEMP$_{j}$ (γ_{011})	..	0.27 (0.07)***	0.34 (0.07)***	0.29 (0.06)***
LNPOP$_{j}$ (γ_{012})	..	..	-0.12 (0.09)	..
IMPORT$_{j}$ (γ_{013})	..	..	0.22 (0.11)*	0.19 (0.06)***
FDI$_{j}$ (γ_{014})	..	..	-0.10 (0.08)	..
For slopes$_{ij}$ ($\beta_{1j} \ldots \beta_{7j}$)				
SIZE$_{ij}$ (γ_{10})	0.07 (0.02)***	0.07 (0.02)***	0.07 (0.02)***	0.07 (0.02)***
AGE$_{ij}$ (γ_{20})	-0.12 (0.04)***	-0.12 (0.04)***	-0.12 (0.04)***	-0.12 (0.04)***
R&D$_{ij}$ (γ_{30})	0.63 (0.07)***	0.64 (0.07)***	0.63 (0.07)***	0.63 (0.07)***
PROF$_{ij}$ (γ_{40})	0.61 (0.20)***	0.63 (0.20)***	0.63 (0.20)***	0.63 (0.20)***
ISO$_{ij}$ (γ_{50})	0.64 (0.12)***	0.64 (0.12)***	0.64 (0.12)***	0.65 (0.13)***
WWW$_{ij}$ (γ_{60})	0.39 (0.07)***	0.39 (0.07)***	0.39 (0.07)***	0.38 (0.07)***
SKILL$_{ij}$ (γ_{70})	0.39 (0.06)***	0.38 (0.06)***	0.38 (0.06)***	0.38 (0.06)***
SECTOR$_{ij}$ dummies	Yes	Yes	Yes	Yes
GROUP$_{ij}$ dummies	Yes	Yes	Yes	Yes
Random effects:				
Intercept$_{ij}$ (u_{0j})	0.42 (86.3)***	0.22 (62.6)***	0.22 (56.7)***	0.21 (60.8)***
SIZE$_{ij}$ slope (u_{1j})	0.01 (53.8)***	0.01 (53.5)***	0.01 (53.6)***	0.01 (53.4)***
AGE$_{ij}$ slope (u_{2j})	0.02 (57.9)***	0.02 (57.9)***	0.02 (57.9)***	0.02 (57.9)***
R&D$_{ij}$ slope (u_{3j})	0.05 (44.2)**	0.05 (44.1)**	0.05 (44.0)**	0.05 (44.0)**
PROF$_{ij}$ slope (u_{4j})	0.55 (47.6)***	0.47 (47.6)***	0.50 (47.5)***	0.47 (47.4)***
ISO$_{ij}$ slope (u_{5j})	0.31 (125.7)***	0.31 (125.2)***	0.31 (125.1)***	0.32 (125.7)***
WWW$_{ij}$ slope (u_{6j})	0.07 (59.2)***	0.07 (59.2)***	0.07 (59.0)***	0.06 (58.9)***
SKILL$_{ij}$ slope (u_{7j})	0.05 (49.0)***	0.05 (48.9)***	0.05 (49.0)***	0.05 (48.9)***
Index of dispersion	0.983	0.984	0.985	0.985
Level-1 firms	15,818	15,818	15,818	15,818
Level-2 countries	28	28	28	28

Note: Non-linear unit-specific model with the logit link function; restricted maximum likelihood (PQL) estimate; coefficients and standard errors in brackets reported for the fixed effects; variance components and Chi-square in brackets reported for the random effects; *, **, *** denote significance at the 10, 5 and 1 percent levels.

But let us first look at fixed effects ($\gamma_{10} \ldots \gamma_{70}$) of the firm-level predictors. All of them are statistically significant and with the expected signs, which is reassuring, because this confirms that the PICS dataset provides reliable information on these variables. As already discussed above, $SIZE_{ij}$ has a positive sign, because larger firms with many product lines are by design more likely to appear with at least one innovated product; in addition to all the other possible advantages of scale. Similarly, the negative coefficient of AGE_{ij} primarily reflects definition of the dependent variable, because new (and therefore younger) firms are more likely to introduce "new to the firm" products when they launch their business.

$R\&D_{ij}$ comes out with positive and highly significant coefficient, showing that this aspect of technological capabilities is actually fairly relevant in the context of developing countries. It would be extremely surprising to find otherwise indeed. A perhaps more substantial finding is that magnitude of the $R\&D_{ij}$ coefficient is similar to the effects of $PROF_{ij}$ and ISO_{ij}, and not that far from the effects of WWW_{ij} and $SKILL_{ij}$. Hence, R&D clearly matters, but it is not the only and even not necessarily the most important input into the innovation process, especially if we consider the joint effect of the other aspects of capabilities. As the literature on developing countries discussed above predicts (Kim, 1980; Dahlman, et al., 1987; Lall, 1992; Bell and Pavitt, 1993), multiple facets of firm's technological capabilities are associated with innovation. Since there are negligible differences across the columns, these results seems to be robust to inclusion of the different country-level variables.

Let us now turn to the effects ($\gamma_{01} \ldots \gamma_{014}$) of the country-level predictors, which are at the core of interest in this paper. As explained above, the output of the factor analysis $TECH_j$ is used as a proxy for the opportunity to benefit from diffusion. Since by definition the extent of the technology gap is in inverse proportion to the value of the factor score, we expect a negative coefficient of this variable, which is confirmed by the results. The advantages of backwardness for "innovation through imitation" prove to be significant, even if the other predictors, including the firm-level effects, are taken into account in the multilevel framework.

All of the other country-level predictors included in the first column, namely $TAXINC_j$, $ENTRY_j$, $EMPREG_j$, $ENFORCE_j$ and $POLITY_j$, came out with expected signs, but not all of them are statistically significant at conventional levels. Not surprisingly, the detrimental effect of $TAXINC_j$ on the propensity of firms to innovate is confirmed by the estimates. A high score of the country on $POLITY_{j,}$ indicating a democratic political system, comes out favourable for innovation in firms. Autocracy not only curtails diversification of knowledge, and therefore creation of new ideas, but even more importantly their diffusion in the society, which is essential for innovation. A somewhat lower but still statistically significant coefficient was obtained for the regulation of $ENTRY_j$ variable. Arguably, less time required to start a new business facilitate inflow of new innovative firms, increase competition and stimulate innovation, hence we would have expected this variable to play a more prominent role.

$EMPRIG_j$ did not come out with a significant coefficient in any specification, which suggests that rigidity (or flexibility) of the labour market regulation does not matter much. Looking from the "varieties of capitalism" perspective (Hall and Soskice, 2001) this outcome actually makes sense, because according to this literature different systems of labour market regulation might produce equally good outcomes in terms of innovation and ultimately productivity.[11] $ENFORCE_j$, which refers to enforcement of contracts, seems to have a rather limited effect too. Again, we should not forget that the dependent variable $INNPDT_{ij}$ is essentially a measure of technology diffusion, which might be hindered by strong enforcement of property rights; especially as far as intellectual property rights are concerned; for which unfortunately there is no direct indicator that could be used in the estimate. It well might be that positive effects of smooth enforcement of contracts tend to be counterbalanced by the potential negative consequences for diffusion pointed out above.

Second, we add the battery of variables on macroeconomic conditions given by $INFLAT_j$, $EXRATE_j$, $CURACC_j$, $FISCAL_j$ and $UNEMP_j$ in the estimate. Macroeconomic instability, represented by inflation $INFLAT_j$ and volatility of the exchange rate $EXRATE_j$, came out with negative and statistically significant coefficients and therefore there is reasonable support for the argument that uncertainty about these nominal parameters undermines innovative efforts of firms. Anybody who has ever attempted to make a budget of an innovation project that often requires a rather long horizon in times of macroeconomic turmoil understands what this is about. Although research on innovation does not pay much attention to these factors, perhaps because most of the literature remains focused on advanced countries for which serious macroeconomic instability is rather rare, the results suggest that these factors certainly should not be neglected in the context of developing countries.

[11] Another possible explanation might be that the EMPRIGj composite index does not measure what it is supposed to, but to the best of our knowledge there is no other available measure of this kind that could be tested against this result in the estimate.

$CURACC_j$ came out significant, whereas $FISCAL_j$ does not seem to matter much. Although external and fiscal deficits spiralling out of control typically hallmark the path to a monetary crisis, these conditions do not seem to have an immediate negative effect on innovation in firms. Actually the opposite is the case for the current account deficit. This arguably reflects the need of technologically catching-up economies to use more resources than they generate, at least at early stages of development. Since overall external balance is determined by flows of money, this should not be a serious problem even for a prolonged period, if the country manages to finance the current account deficit with inflow of financial capital from abroad. Another positive and statistically significant effect was detected for $UNEMP_j$, which at the first glance might seem counterintuitive. However, idle resources may facilitate innovation projects that require new production facility, compared to a situation when the firm needs to attract labour from existing use.

Third, we extend the model by the $IMPORT_j$ and FDI_j variables of inward openness and control for size of the country by adding $LNPOP_j$ along the way. Import of goods and services $IMPORT_j$ comes out with a positive but only weakly statistically significant coefficient, whereas inflow of FDI_j inflow does not seem to be relevant. It should be mentioned that we have also tested a variable of inward stock (not only current inflow) of FDI (in % of GDP) with very similar results. Accounting for $LNPOP_j$ does not seem to matter, at least as far as a coefficient of this variable is concerned. A cursory comparison with the previous estimates reveals that with the exception of the $ENFORCE_j$ variable the results seem to be robust to the different specifications.

As anticipated above, the last column presents the “best” model, which includes only the statistically significant explanatory factors of differences in the propensity of firms to innovate. Since non-significant variables do not really contribute much to the model, and there is a relatively low number of countries in the sample, reduction in the number of coefficients improves accuracy and efficiency of the estimate. Nevertheless, the results are not much affected, except that statistical significance of the retained variables increases.

It should be stressed, furthermore, that the results do not suffer from a serious problem of multicollinearity, neither among the firm- or country-level predictors. Among the firm-level predictors the correlation coefficient never exceeds 0.40, which confirms that these variables capture distinct characteristics of firms. A brief look at the correlation table between the country-level predictors, not reported for the sake of space, reveals that the main potential problems are the correlation coefficient of 0.63 between $IMPORT_j$ and FDI_j, and to a lesser extent the correlation coefficient of 0.53 between $LNPOP_j$ and $CURACC_j$. But a closer examination of the results with this in mind revealed that the results are not seriously affected by the overlap between these variables. [12]

So far we have focused only on the fixed effects. Country-level random effects are reported in the lower part of the table. As envisaged by the multilevel nature of the model, the error term is split into multiple components. All of the random effects are

[12] No other correlation coefficient between pairs of country-level predictors exceeds 0.50. Students of macroeconomics should put forward that $INFLAT_j$ and $EXRATE_j$, but also $CURACC_j$, $FISCAL_j$ and $UNEMP_j$ are intertwined, but this is not supported by the facts, at least in this sample, because correlation between these variables is rather low.

statistically significant at conventional levels, which confirms that there are important differences across countries in the likelihood of firms to innovate and in how the firm-level effects affect this propensity. [13] A sizeable part of the unexplained variability of firm's innovativeness across countries has been accounted for, because the magnitude of the random effect for the intercept decreased from 0.64 in a model that would have no country-level predictors to 0.42 in the first column and down to 0.21 in the last column.

Another diagnostic measure of multilevel models that has not been discussed yet is the so-called index of dispersion. Although logit multilevel models do not have a separate term for the level-1 error, we can calculate a level-1 error variance scaling factor that measures the extent to which the observed errors follow the theoretical binomial error distribution (Luke 2004, pg. 57). If the index of dispersion equals to 1, there is a perfect fit between the observed errors and the theoretical assumptions. A significant over- or under-dispersion indicates model misspecification, the presence of outliers or the exclusion of an important level in the model. Less than 5% dispersion is usually seen as satisfactory, which is the case here.

To further illuminate the implications of the analysis, we compute the predicted probabilities of firms to innovate based on results of the "best" model in selected situations. Table 5 shows this exercise. Firms with different technological capabilities,

[13] Since the HLM (version 6.04) package assumes that the variances may not be normally distributed, a chi-square test of the residuals can be performed (Raudenbush, et al. 2004). It is important to stress, however, that the meaning of this significance test is not the same as for an ordinary variable and the results should be interpreted with caution. Since the variances are bounded at zero, their distributions are not normal, whereas we generally expect them to be non-zero, which makes Luke (2004, pg. 32) to point out that it is more sensible to interpret (and compare between estimates) magnitude of the residuals rather than their significance. For this reason some statistical packages, such as R or S-plus, do not even report any significance tests for the random part of the model.

given by scores on the variables in the CAP_{ij} vector, delineate rows of the table. We distinguish three situations: 1) Min(CAP_{ij}) refers to an "incapable" firm with zero scores on technological capabilities; 2) Mean(CAP_{ij}) denotes a typical firm with mean scores; and 3) Max(CAP_{ij}) refers to a top firm, which nurtures all of the technological capabilities taken into account here.[14] Alternative specifications of the country, given by the factor score on $TECH_j$ and scores on the CON_j vector of the other national conditions, are in columns. Apart from mean scores on these, we report the worst and best countries: 1) Cambodia at the bottom of the technology ladder with the lowest score on $TECH_j$; 2) Ireland at the technological frontier with the highest score on $TECH_j$; 3) Egypt with the less favourable combination of CON_j; and 4) Poland that provides the most favourable combination of CON_j. Everything else is hold constant on average.

Table 5: Selected predictions of the econometric estimate

		Min(CAP_{ij})	Mean(CAP_{ij})	Max(CAP_{ij})
Mean($TECH_j$)	Mean(CON_j)	22.7	37.0	75.5
Cambodia($TECH_j$)	Mean(CON_j)	35.0	51.9	85.0
Ireland($TECH_j$)	Mean(CON_j)	16.7	28.7	67.8
Mean($TECH_j$)	Egypt(CON_j)	6.6	12.4	42.7
Mean($TECH_j$)	Poland(CON_j)	43.1	60.4	88.9

Firm-level technological capabilities are essential. All else equal to average, the estimated probability to innovate is 22.7% for a firm with the minimum technological capabilities, but 75.5% for the top firm. Nevertheless, this is not the full story, because the national environment also matters considerably. An otherwise average firm

[14] For the max(CAP_{ij}) category the upper value of $PROF_{ij}$ has been truncated at 50% of employment. Although some firms may maintain even higher share, this is not viable in most kinds of trades; and therefore not a relevant situation to consider here.

located in Cambodia comes out with 23.2 percentage points higher probability to innovate than a firm with the same characteristics nested in Ireland; just thanks to the higher potential for imitation. Even more difference makes the joint effect of the other national conditions. A firm embedded in the Polish framework is estimated to be by 48 percentage points more likely to innovate than an otherwise same firm operating under Egyptian conditions; holding all other factors constant. Just to give concrete examples how multilevel modeling can be used to derive insights about impact of factors operating at different levels.

7. Conclusions

The aim of this paper was to illustrate how empirical research on innovation can benefit from multilevel modeling. Using the multilevel approach we have demonstrated that it is possible to use quantitative econometric methods to directly test hypotheses on impact of the national framework conditions on likelihood of firms to innovate. Multilevel modeling appears to be a promising new item in the tool box of research on innovation, which may allow us to formally test complex predictions of the contextual theories of innovation.

Given the results of the estimates, what have we learnt about innovation in developing countries? At the most general level, the main conclusion is that innovation should be analyzed as a multilevel phenomenon. Although innovation ultimately depends on technological capabilities of firms, the environment within which they operate also turns out to be an integral part of the picture. Apart from firm's size, age and a broad range of capabilities, national economic, technological and institutional conditions are confirmed to directly predict the likelihood of firms to innovate. Among the country-level variables, one of the most robust predictors proves to be the extent of technological backwardness of the country where the firm operates, which represents the potential for transfer of advanced technologies from abroad. Nevertheless, policy makers can do much to facilitate innovation in firms, because a favourable national framework explains a fair share of the variance too.

Although we have constrained ourselves only to the "intercept-as-outcome" multilevel model in this paper, there is a variety of specifications that in principle could be estimated. A straightforward extension would be to consider the various cross-level interaction terms between the firm- and higher-level predictors, which can not be done here due to limits of the data. Another possible avenue for further research would be to take into account a more complicated hierarchical structure. For example, we can specify 3-level models with firms in regions within countries or so-called cross-classified models with firms simultaneously nested in sectors and countries. All that matters is access to suitable data, which unfortunately remains scarce.

Although some general implications have been derived, it should be emphasized that the main purpose of this paper has been to highlight a promising direction for future research rather than to offer concrete guidance for policy. Since we have a relatively small number of countries in the dataset, the results could be sensitive to composition of the sample. Further research on even more extensive datasets is clearly needed to confirm these findings.

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